Pre-processing Strategies to Improve Longitudinal MRI Repeatability

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Introduction

In longitudinal studies, it is important to get the same imaging plane from scan to scan and from day to day. This important job lies on the reproducibility of the operator(s) which usually varies a lot. The remedy to date is to apply post-processing technique to co-register them together in the same spatial coordinates. In order to look at the fine difference between scans especially during different days, we proposed a change in paradigm by registering a scout scan to previous scan to accurately prescribe the scan planes. This idea is demonstrated in this paper with mouse brain MRI.

Comparing to human brain MRI, mouse brain size is smaller and the brain surface is smoother which leads to less reliable registration in mouse brain MRI. The problem is less symptomatic in true 3D datasets. However, 2D scan is usually preferred as it takes less time to achieve high spatial resolution and is also less susceptible to physiological motion artifacts than 3D scan. A strategy to accurately position the scan planes according to previous scan would be ideal to avoid interpolation error in post-processing associated with anisotropic voxels in 2D dataset. The same strategy would yield results that shed light on the accuracy of image registration algorithms/software, which would have a strong implication on the accuracy of spatial normalization and localization in small animals [1].

Methods

MRI was performed on 4.7T Bruker Biospec Avance system (Bruker BioSpin GmbH, Germany) with a 20 G/cm active shielded gradient coil and a stock mouse birdcage coil. T2-weighted mouse brain images were acquired with RARE sequence [2] with FOV=20mm, TR=2000ms, TEeff=40 to 48ms, ETL=8, with in-plane spatial resolution of 170 µm x 170 µm and 78 µm x 78 µm and slice thickness of 340 µm to 1000 um. Each protocol with different spatial resolution, averages, and thickness were repeated at least twice with different translations and rotations. The exact scanner coordinates were recorded and relative translations in x/y/z in mm and relative rotations in pitch/row/yaw in degree between scans were recorded as "*gold standard*". Images were registered with rigid body affine transform to the first scan of each protocol using SPM99. The voxel dimensions in the image header were expressed in x100 µm rather than x1000 µm. The estimated relative transform matrix with 3 translations in x100 µm unit and 3 rotations pitch/roll/yaw in degree format were converted to scanner coordinates which were then used to position the image acquisition plane. In addition, since the exact scanner coordinates between scans were known, this estimated acquisition plane were compared to the "*gold standard*" scanner coordinates. The estimated translational and rotational parameters were subtracted by the corresponding parameters from the "gold standard" forming the true registration errors.

Results

The true translational and rotational errors were plotted in Fig. 1 and Fig. 2 respectively. Note that datasets 3, 4, and 5 were of 170 µm x 170 µm x 340 µm while the rest were either 78µm x 78 µm x 500 µm or 78µm x 78 µm x 1000 µm. The progressive reduction of true rotational error was only due to the change from TE=40ms (dataset 3) to TE=48ms (dataset 4) which provide more T2 contrast and from NEX=4 (dataset 3 &4) to NEX=8 (dataset 5) which provide more SNR. All datasets uses different small rotation angles (<4 degrees) except dataset 6 which has pitch/roll/yaw change of 10/7/9 degree. All datasets were having small Z shift of less than 0.3 mm except dataset 7 which has a shift of 0.52 mm. The datasets from 6 to 11 were dead mice and the error trends appeared to be similar to live mice from datasets 1 to 5. Very accurate in-plane rotation correction (yaw rotation) were obtained within an accuracy of ± 0.4 degree both for live and dead mice but the same was not true for pitch and roll rotation corrections which were within ± 1.3 degree after taken out the a few special datasets (3, 4, 6, &7) that were described. Preliminary results on image guided acquisitions were shown in Fig. 3 showing only the mid slice. Fig 3a was the prior scan. Fig. 3b was the next scan. Fig 3c was the acquisition along the estimated plane after considering the matching between 3b with 3a.

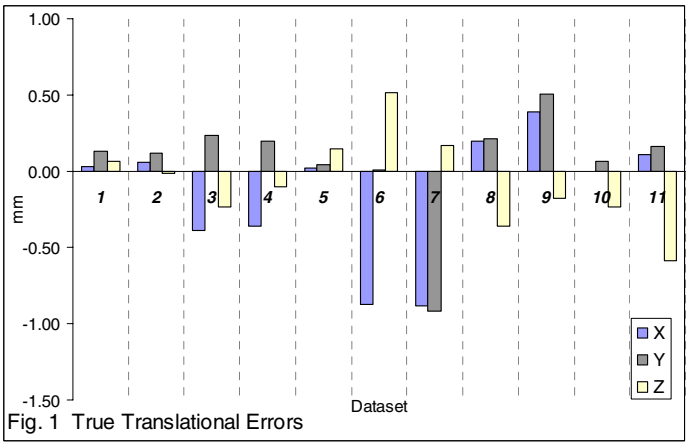


Fig. 1 True Translational Errors

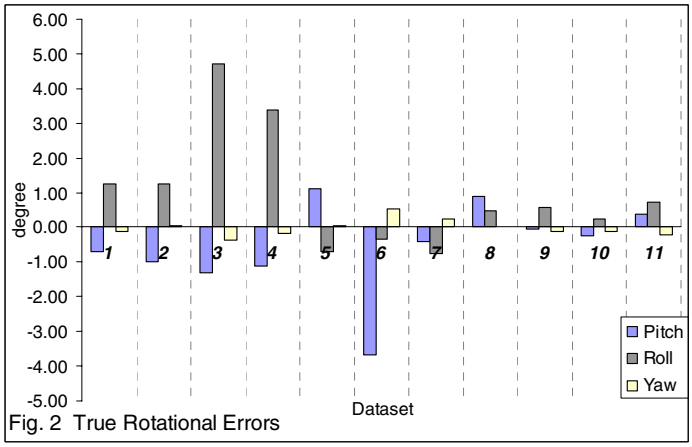
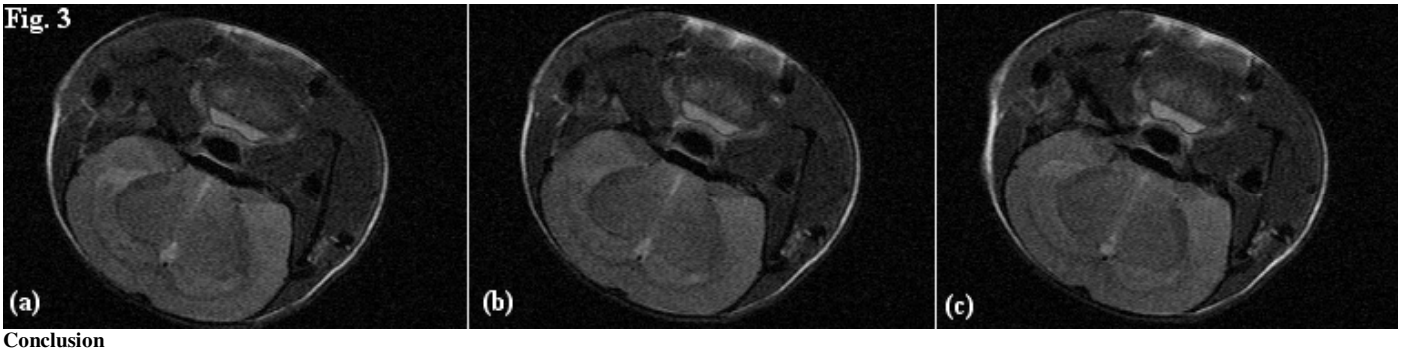


Fig. 2 True Rotational Errors



Conclusion

We demonstrated a pioneer attempt to use image registration to previous scan in order to achieve accurate positioning in mouse brain MRI. We also demonstrated the use of SPM99 in mouse brain registration, along with its true registration errors. This strategy can be used to fine tune/validate image registration algorithms in MRI. Future work would be to expand it to human brain registration to characterize the registration accuracy of different packages.

References

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